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# CPUE standardization of yellowfin tuna caught by Korean tuna longline fishery in the Indian Ocean

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## Abstract

In this study, CPUE (catch per unit effort) standardization for yellowfin tuna of Korean longline fishery in the Indian Ocean was conducted by Generalized Linear Model (GLM) using operational (set by set) data to assess the proxy of the abundance index. The data used for GLM were catch (in number), effort (number of hooks) and number of hooks between floats (HBF) by year, month and area. Yellowfin tuna CPUE by Korean tuna longline fishery was standardized for the whole, west and east areas. The standardized CPUE trends were different between west area and east area. The standardized CPUE for whole area was about 7.8 in 1977, and showed sharply decreased after that. During 1980s it showed a level of 3-4, but again decreased thereafter, and since the mid-1990s it showed the steady trend with a level of about 1.0. The standardized CPUE for west area showed a similar trend with those of whole area, but showed the large increasing in 2003-2005 and 2013. However, the standardized CPUE for east area had decreased since 1977, and is showing the low level of below 1.0 in recent years.

## Introduction

Yellowfin tuna in the Indian Ocean has been one of the highest catch in Korean tuna longline fisheries along with bigeye tuna. Yellowfin catch considerably increased from the mid-1960s and peaked at about 34 thousands mt in 1978, but had decreased with a fluctuation to a few hundred tons in recent years (Fig. 1). In this study, yellowfin CPUE (catch per unit effort) standardization of Korean tuna longline fisheries in the Indian Ocean (1978-2011) was conducted using Generalized Linear Model (GLM) to assess the proxy of the abundance index.

## Data and Methods

In this study, operational (set by set) data of Korean tuna longline fishery were used for yellowfin tuna CPUE standardization, which complied from captain onboard and contained catch (number of fishes), effort (number of hooks) and HBF (number of hooks between floats) by year, month and area from 1978 to 2013. The data prior to 1977 were not used because there were many missing information in the dataset to conduct GLM.

Based on the fishing patterns of Korean tuna longline fishery and biology on yellowfin tuna (Langley et al., 2012), area was classified into 2 large areas for standardizing yellowfin tuna CPUE of Korean tuna longline fishery (Fig. 2). The CPUE standardization was conducted for three cases which are whole area (R1+R2+R3+R4+R5), west area (R1+R2+R3) and east area (R4+R5).

Monthly data were combined into 2 seasons (by a half year). The reason is that there is missing values in some quarters.

The HBF was divided into 3 classes (class 1: below 9 hooks, class 2: 10-14 hooks, class 3: above 15 hooks) based on the operational patterns of Korean tuna longline fisheries (Lee et al., 2014).

Generalized Linear Models (GLM) for yellowfin tuna CPUE standardization for each area are as follows, and the analyses were conducted by SAS program (ver. 9.2).

**Whole area**: $\mathrm{Ln}(CPUE + c) = \mu + Y + S + A + G + Y\times A + S\times A + A\times G + S\times A\times G + error$

**Specific area (west and east)**: $\mathrm{Ln}(CPUE + c) = \mu + Y + S + G + Y\times S + S\times G + error$

*where, CPUE: catch in number of yellowfin tuna per 1,000 hooks*

*c: 10% of average overall nominal CPUE*

*Y: effect of year*

*S: effect of season (2 seasons)*

*A: effect of area (2 areas)*

*G: effect of gear (3 classes)*

*Y×A: interaction term between year and area*

*S×A: interaction term between season and area*

*A×G: interaction term between area and gear*

*S×G : interaction term between season and gear*

*S×A×G : interaction term among season, area and gear*

*error: error term*

## Results and Discussion

Fig. 3 shows the standardized CPUE trends of yellowfin tuna for the whole area with nominal CPUE in real and relative scales. The standardized CPUE was about 7.8 in 1977, and showed sharply decreased after that. During 1980s it showed a level of 3-4, but again decreased thereafter, and since the mid-1990s it showed the steady trend with a level of about 1.0.

The standardized CPUE for west area showed a similar trend with those of whole area, but showed the large increasing in 2003-2005 and 2013 (Fig. 4).

For the standardized CPUE for east area, it had decreased since 1977, and is showing the low level of below 1.0 in recent years (Fig. 5).

The ANOVA (type 3) results for the GLMs are shown in Table 1. As for the whole area model, it suggests that area effect is the largest factor affecting the nominal CPUE.

Figs. 6, 7 and 8 show frequency distribution, Q-Q plots and box plots of the standardized residuals, respectively.

## References

Langley, A., M. Herrera and J. Million, 2012. Stock assessment of yellowfin tuna in the Indian Ocean using MULTIFAN-CL. IOTC-2012-WPTT14-38 Rev_1, 1-72.

Lee, S.I., Z.G. Kim, J.E. Ku, M.K. Lee, H.W. Park, S.C. Yoon and D.W. Lee, 2014. Review of catch and effort for albacore tuna by Korean tuna longline fishery in the Indian Ocean (1965-2013). IOTC-2014-WPTmT05-17 Rev_1, 1-11.

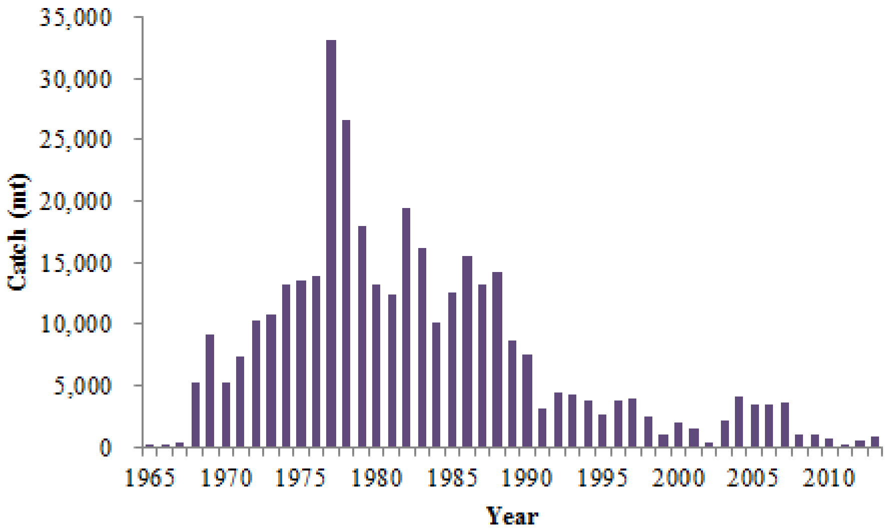



Fig. 1. Annual catch of yellowfin tuna caught by Korean tuna longline fishery in the Indian Ocean, 1965-2013 (Data source: IOTC database).

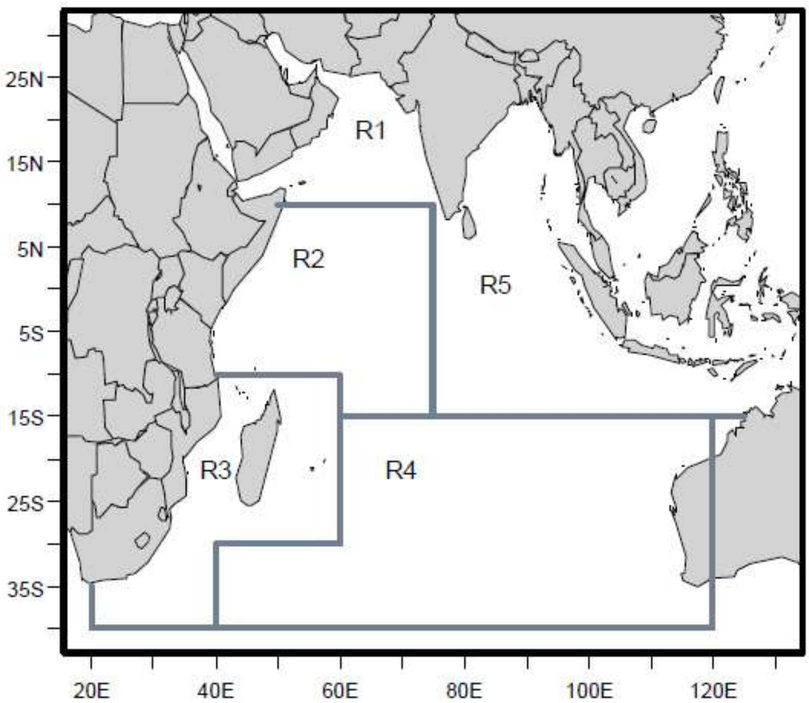



Fig. 2. Map showing areas used for yellowfin tuna CPUE standardization of Korean tuna longline fishery in the Indian Ocean (West=R1+R2+R3, East=R4+R5).

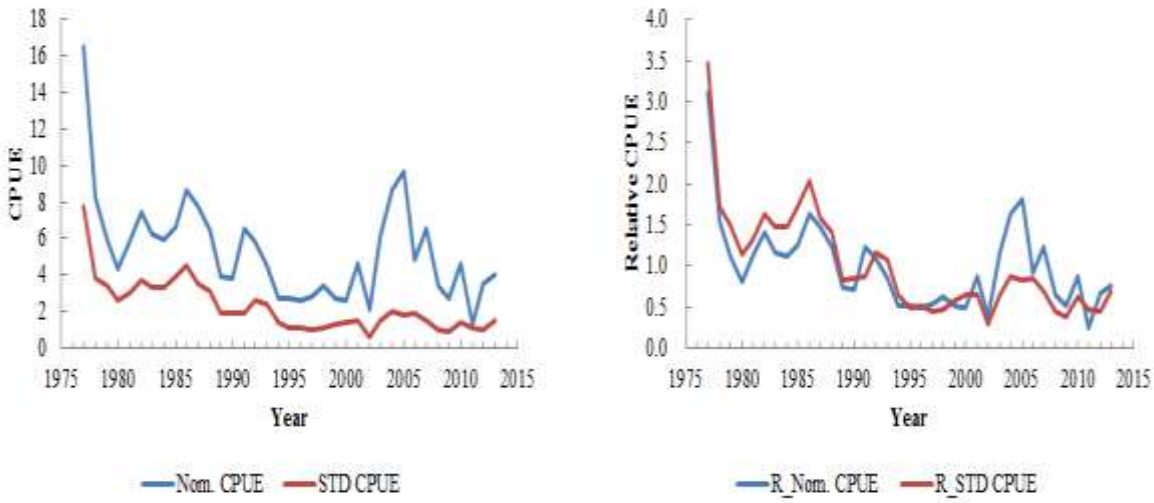



Fig. 3. Standardized (STD) and nominal CPUEs of yellowfin tuna for the whole area of Korean tuna longline fishery in the Indian Ocean, 1977-2013.

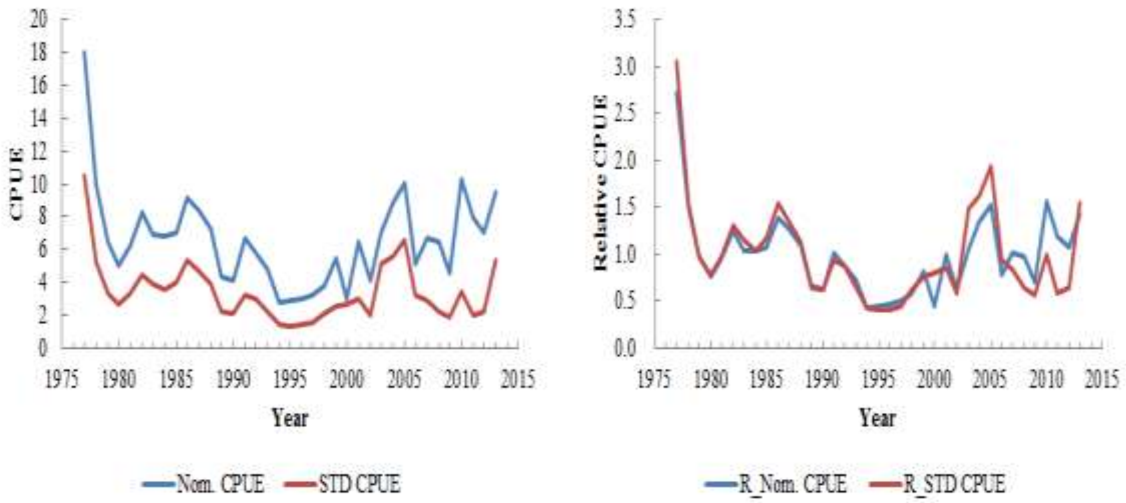



Fig. 4. Standardized (STD) and nominal CPUEs of yellowfin tuna for the west area of Korean tuna longline fishery in the Indian Ocean, 1977-2013.

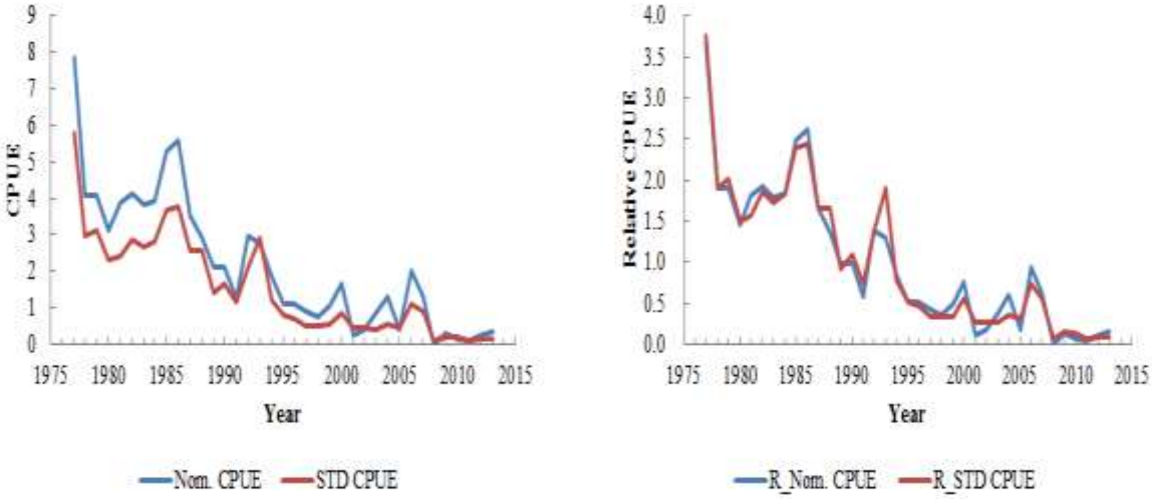
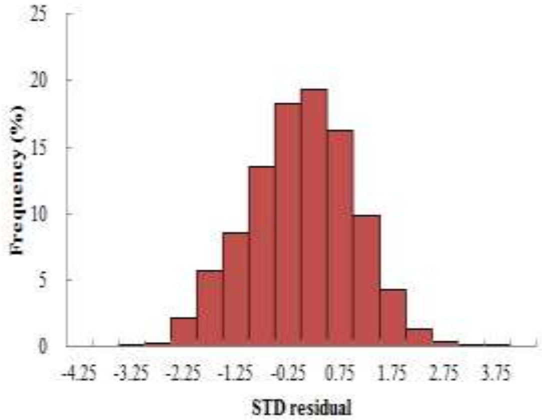
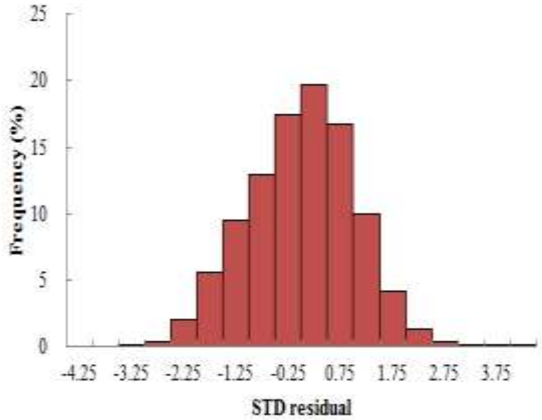


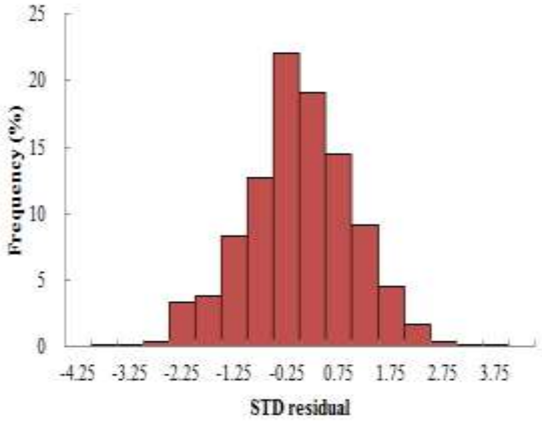

Fig. 5. Standardized (STD) and nominal CPUEs of yellowfin tuna for the east area of Korean tuna longline fishery in the Indian Ocean, 1977-2013.




(a) Whole area

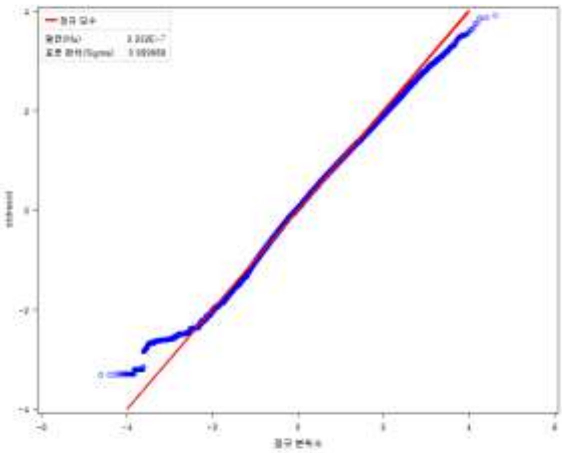



(b) West area

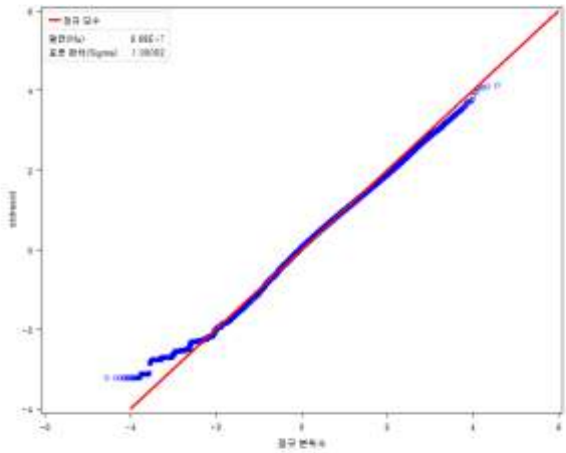



(c) East area

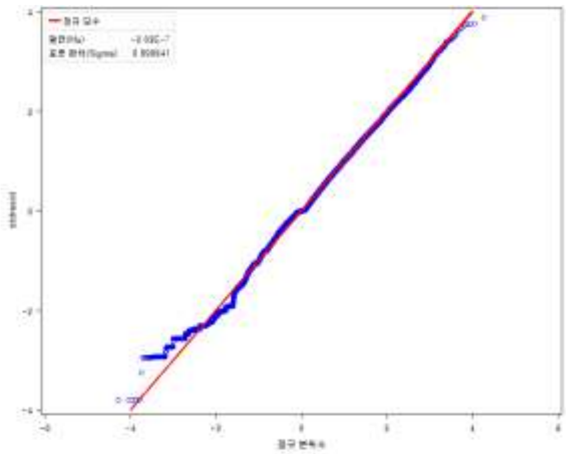
Fig. 6. Distributions of the standardized residual for the GLM analyses.



(a) Whole area

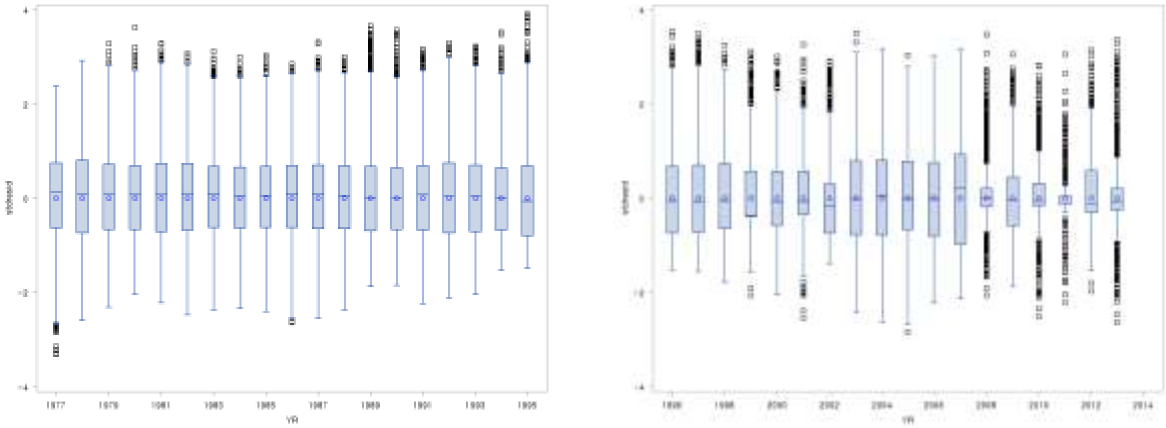


(b) Tropical area

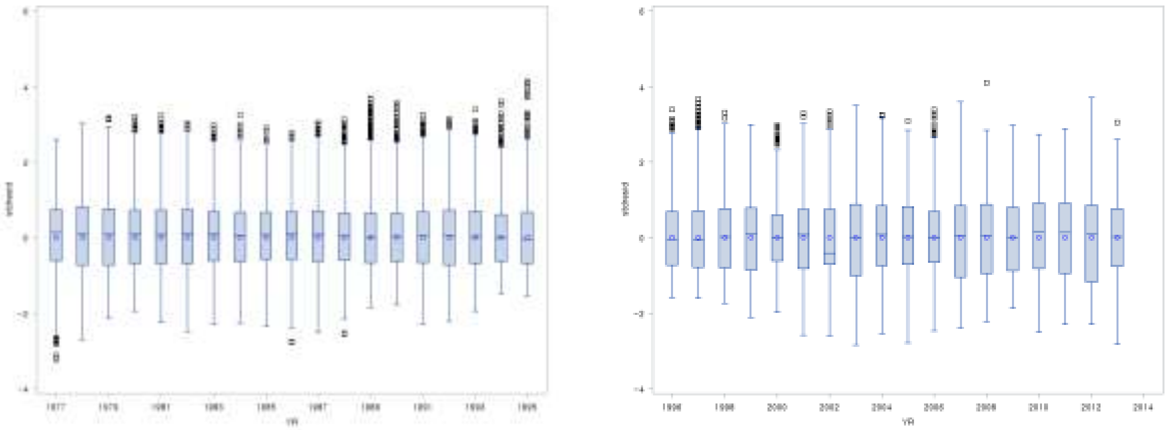


(c) South area

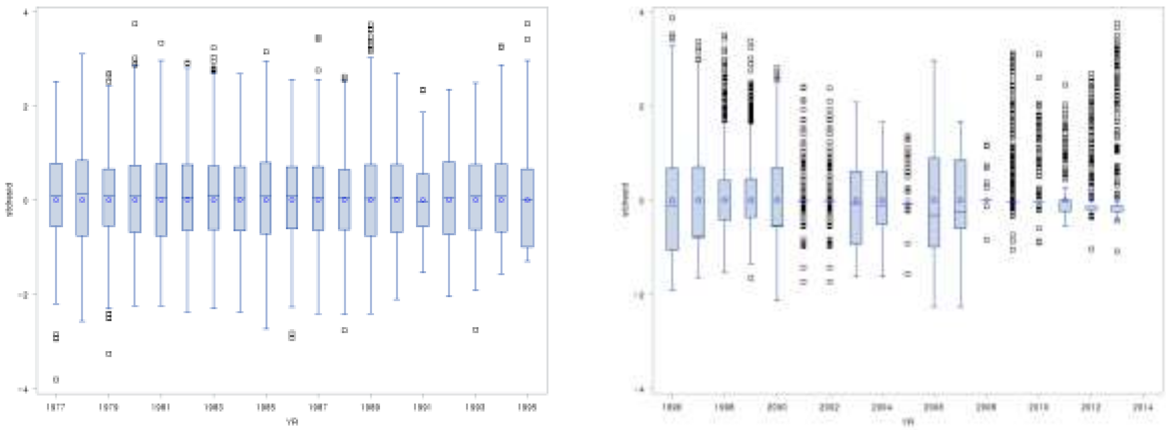
Fig. 7. QQ-plots of the standardized residual for the GLM analyses.



(a) Whole area



(b) West area



(c) East area

Fig. 8. Box plots of the standardized residual by year for the GLM analyses. Circle: mean, box: 25th and 75th percentile, horizontal line in the box: median, bars: maximum and minimum observation between 1.5 IQR (interquartile range) above 75th percentile and 1.5 IQR below 25th percentile, squares: outliers.

Table 1. ANOVA results of the GLM for yellowfin tuna CPUE standardization

(a) Whole area

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| **Model** | 83 | 77390.757 | 932.4188 | 1022.24 | <.0001 |
| **Error** | 308047 | 280979.87 | 0.9121 | | |
| **Corrected Total** | 308130 | 358370.63 | | | |

| R-Square | Coeff Var | Root MSE | lncpue Mean |
|---|---|---|---|
| 0.215952 | 74.87054 | 0.955057 | 1.275611 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| **YR** | 36 | 17721.908 | 492.27523 | 539.7 | <.0001 |
| **S** | 1 | 200.80107 | 200.80107 | 220.14 | <.0001 |
| **A** | 1 | 4935.1487 | 4935.1487 | 5410.56 | <.0001 |
| **G** | 2 | 29.21238 | 14.60619 | 16.01 | <.0001 |
| **YR*A** | 36 | 6060.3801 | 168.34389 | 184.56 | <.0001 |
| **S*A** | 1 | 79.90564 | 79.90564 | 87.6 | <.0001 |
| **A*G** | 2 | 1083.5301 | 541.76505 | 593.95 | <.0001 |
| **S*A*G** | 4 | 740.99964 | 185.24991 | 203.1 | <.0001 |

(b) West area

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| **Model** | 77 | 39001.838 | 506.5174 | 566.73 | <.0001 |
| **Error** | 244599 | 218612.5 | 0.8938 | | |
| **Corrected Total** | 244676 | 257614.34 | | | |

| R-Square | Coeff Var | Root MSE | lncpue Mean |
|---|---|---|---|
| 0.151396 | 65.37584 | 0.945388 | 1.446082 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| **YR** | 36 | 25509.881 | 708.60781 | 792.84 | <.0001 |
| **S** | 1 | 410.43252 | 410.43252 | 459.22 | <.0001 |
| **G** | 2 | 739.9685 | 369.98425 | 413.96 | <.0001 |
| **YR*S** | 36 | 6258.2004 | 173.8389 | 194.5 | <.0001 |
| **S*G** | 2 | 77.44122 | 38.72061 | 43.32 | <.0001 |

(c) East area

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| **Model** | 77 | 32360.09 | 420.26091 | 435.61 | <.0001 |
| **Error** | 63376 | 61142.965 | 0.96477 | | |
| **Corrected Total** | 63453 | 93503.055 | | | |

| R-Square | Coeff Var | Root MSE | lncpue Mean |
|---|---|---|---|
| 0.346086 | 205.9263 | 0.982225 | 0.476979 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| **YR** | 36 | 11436.302 | 317.67505 | 329.28 | <.0001 |
| **S** | 1 | 122.361 | 122.361 | 126.83 | <.0001 |
| **G** | 2 | 416.75802 | 208.37901 | 215.99 | <.0001 |
| **YR*S** | 36 | 1293.6586 | 35.93496 | 37.25 | <.0001 |
| **S*G** | 2 | 111.75289 | 55.87644 | 57.92 | <.0001 |